CHARACTERIZATION OF A SAUSAGE ASSORTMENT MADE FROM BEEF AND PORK LIVER: A COMPARATIVE STUDY

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Abstract

The study aimed to determine the influence of the amount of liver introduced into two varieties of liver sausages, pork and beef, on the quality properties of these products. The sausages were made from raw materials from two species (pork and beef) with additions of 25% liver and 50% liver, respectively, resulting in four experimental batches of products: BL25 (sausages with 25% beef liver), BL50 (sausages with 50% beef liver), PL25 (sausages with 25% pork liver), PL50 (sausages with 50% pork liver). Product quality was assessed in terms of chemical composition, instrumental color, pH, and sensory quality. The results showed higher protein contents for batches made with 50% liver, both for pork (19.18%) and beef (19.34%), compared to batches where only 25% liver was added. The same trend was observed for the moisture content; samples made with 50% liver showed higher moisture content compared to those with 25% liver. Increasing the percentage of liver added in the technological process caused a decrease in the lightness (L*) both in the external appearance and cross-sectional aspects of the beef-based batches. In contrast, the increse in liver content led to a rise in the average values for the a* (red-green) coordinate. These two parameters are directly influenced by the percentage of liver in the sausages, through the presence of myoglobin and hemoglobin, which are proteins that contain heme iron.

Key words: meat processing, beef/pork liver sausages, quality indicators

Over the last 60 years, there has been a significant shift in meat consumption trends. Bonnet C. *et al* (2020) reported that in 1961, plant products, mainly wheat products, were the primary source of available protein, providing 26 g per capita per day, which accounted for 52% of available protein in the European Union (EU). In contrast, meat contributed only 17 g per capita per day.

Currently, according to González N. *et al* (2020), animal products now account for up to 58% of protein availability, with meat products being the leading source of protein, supplying 28 g per person per day and covering 30% of total calorie consumption.

The growth of the global middle-class population and changes in food supply have led to substantial shifts in dietary patterns, particularly in the consumption of meat and meat products. An increase in meat consumption has been observed among the population, with Basu S. (2015) noting a 204% increase between 1960 and 2010. Other authors have reported an even higher increase in meat consumption for the more recent period from 1992 to 2016, with a 500% rise (Katare B. *et al*, 2020). Future projections also indicate a potential increase in consumption of up to 388 million tonnes by 2030 and 460–570 million tonnes by 2050 (Libera J. *et al*, 2021).

The definition of meat, as per Council Regulation (EC) No. 700/2007 dated June 11, 2007, also encompasses offal, which is a by-product of animal slaughter and is recognized as a high-nutritional-value product. Certain nutrients, particularly minerals such as iron, zinc, magnesium, and calcium, are found in higher levels in the calf and beef liver compared to muscle tissue (Florek M. *et al*, 2012; Biel W. & Kowalczyk A., 2019).

By-products in general and liver in particular, are processed and incorporated into various food products, offering competitive nutritional value. The manufacturing of liver sausage is a well-known practice in many countries, resulting in a wide range of product varieties distinguished by raw materials, optional additions, and seasoning blends (Biel W. & Kowalczyk A., 2019; Florowski T. *et al*, 2021).

Meat products containing liver are renowned for their smooth, rich, and spreadable texture, as they are primarily emulsified products with high-fat content, occasionally reaching percentages as high as 40%. While this aspect enhances textural

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and flavour properties, it may also be viewed negatively by consumers due to the association of high-fat and saturated fatty acid products with the risk of certain cardiovascular diseases (Barbut S. *et al*, 2021; Florowski T. *et al*, 2021).

The challenge for processors in the meat industry is to create high-quality products that are both nutritionally and sensorially appealing, in order to meet market and consumer demands, while also considering the optimal utilization of raw and auxiliary materials to promote sustainability.

The present study aimed to produce and characterize liver sausages, diversified by the species of origin of the liver (pork / beef) and the percentage of added liver (25% / 50%). This assortment is traditionally known as 'caltaboşi' and is made in Romania using pork offal and meat, with or without the addition of rice. These products can be consumed fresh or smoked. For the four batches produced, the objective was to characterize them based on pH value, instrumental color, chemical composition, and sensorial quality, while also identifying the extent of influence of these two factors on the finished products.

MATERIAL AND METHOD

The research took place at the Meat Processing Section and the Meat and Meat Products Technology Laboratory of the University of Life Sciences in Iasi.

Experimental design

For the fabrication of the four experimental batches of sausages, the necessary raw materials were procured from the local food market. Table 1 provides an overview of the raw and additional materials essential for producing each of the four assortments.

The experimental protocol consisted in the manufacture of four categories of sausages: two batches with beef liver and two batches with pork liver (25% liver, 5% fat, 15% offal and 50% liver, 10% fat, 10% offal). The other ingredients were added in the same proportions in all samples: pork trimmings, rice (10%), salt (2%), onion powder (1.5%), black pepper (0.5%), nutmeg (0.15%).

Table 1

Formulations to prepare the sausages

Batch code	**Ingredients (%)**						
	Beef liver	**Pork liver**	**Pork trimings**	**Offal**	**Pork backfat**	**Rice**	**Total**
BL25	25	-	45	15	5	10	100
BL50	50	-	20	10	10	10	100
PL25	-	25	45	15	5	10	100
PL50	-	50	20	10	10	10	100

Sausage production

The raw meat was passed through a grinder (GRINDER WP - 105) through a 0.8 cm diameter sieve. The rice used in the technological process of obtaining the sausages is washed beforehand, then it is pre-cooked for 20-30 minutes, after which it is cooled so that it can be mixed with the raw materials and spices. To produce the final composition, the meat, liver, fat and pre-cooked rice are transferred into the mixer (CUTTER TITANE V 45L) and mix to homogenize for 10-15 minutes, depending on the quantity and the binding state of the raw material. After mixing, the composition is transferred to the filling machine (REX RVF 220), which is equipped with vacuum and continuous operation. The edible pork membranes used were prepared at least 30 minutes prior to the filling stage by immersing in water at a temperature of approx. 50°C in order to remove excess salt and obtain membrane elasticity.

After filling, the next step is to tie the sausages and then place them on the racks. The sausages are twisted one by one to form individual pieces of 10 cm each, then tied at both ends in the shape of the letter 'U'.

The shaped sausages are then stamped to remove any air voids formed during the filling process, placed on the smoker trolley's grates and placed in the cell for heat treatment (Table 2).

Table 2

Heat treatment scheme of the sausage batches

Heat treatment stage	Time	Temperature inside the cell	Temperature in the thermal centre	Humidity
	minutes	°C	°C	%
Air drying	20	62	45	30
Boiling	-	72	69	99
Hot air drying	10	86	69	30
Cooking	30	86	69	30

The products were stored under refrigerated conditions (2-4°C) until the proposed analyses were performed.

Proximate analyses

The chemical characterization involved the determination of the proximate chemical composition, including the assessment of moisture, fat content, and protein levels. These measurements were conducted using a spectrophotometer, specifically the Food-Check analyzer, which utilizes an infrared light source.

The physical characterization of the samples encompassed instrumental color assessment, and evaluation of pH values. Color analysis of the samples was performed using the portable Konica Minolta Chroma Meter CR-410, within the three-dimensional CIE color system. The measurements included L*, a*, and b* color parameters, employing the D65 illuminant at an observation angle of 10 degrees. Prior to measurements, calibration of the instrument was executed on a white calibration plate to establish standard values. pH measurements were conducted with the aid of a HANNA HI99163 digital pH meter. This device is equipped with an amplified pH electrode that incorporates an integrated temperature sensor.

Sensory evaluation

For the sensory evaluation of the liver sausages, a group of 30 potential consumers from the student body at the University of Life Sciences were selected. The panel members, ageing from 20 to 25 years, were selected according to Lawless H. T. *et al* (2010).

The sensory evaluation involved conducting a hedonic acceptance test on a 9-point scale. In this test, participants were instructed to assess the samples based on attributes such as appearance, color, flavour, taste, firmness, and overall acceptance (with 1 being extremely undesirable and 9, extremely desirable). The samples were presented for the evaluators in approximately 2 cm thick pieces, each identified by a unique three-digit number for codification.

Statistical analysis

To analyze the rezults, the values were compared for proximate composition, color parameters, pH and the acceptability test using an analysis of variance (ANOVA) followed by Tukey's test at a 5% significance level ($p < 0.05$). The statistical analyses were conducted using the XLStat software (version by Addinsoft, 2023).

RESULTS AND DISCUSSIONS

In terms of pH levels, the examination of liver sausages revealed average pH values ranging from 6.38±0.04 (PL50) to 6.89±0.07 (BL50). These values exceeded those documented by Belleggia L. *et al* (2022), who reported a mean pH of 5.25 ± 0.28 for fermented liver sausages from various producers. This discrepancy can be attributed to the inherent characteristics of the sausages. It is important to emphasize that the safety of fermented sausages is intricately linked to their pH levels. An acidic pH inhibits the proliferation of spoilage and potentially harmful microorganisms naturally present in the raw ingredients. In the case of fermented sausages, the pH gradually decreases as fermentation commences, typically reaching as low as 4.4 (Belleggia L. *et al*, 2022). Conversely, the sausages analyzed in this study underwent heat treatment, which prevented a decline in pH. Furthermore, the observed pH values exceeded those reported by Florowski T. *et al* (2021) for liver sausages enriched with walnut paste, where the control sample exhibited a pH value of 6.13 ± 0.03. Similar pH values were documented by Di Cagno *et al* (2008), describing liver sausages with pH values ranging from 5.99 to 6.62. These variations underscore the significance of pH levels in ensuring the safety and characteristics of fermented sausages, with differences arising due to product type and processing methods.

Regarding colour measurements, the study followed both the surface colour and section colour of the products. When analyzing the surface colour it was found that increasing the liver content caused a significant descrease in lightness (L*), only in case of the beef liver sausages. In terms of redness, there was a significant increase in a* value for both beef liver and pork liver sausage samples due to the increase in the percentage of liver in the recipe. Furthermore, the values of the colour parameter a* were higher for the sausage samples that included pork liver. However, statistically, the species of origin of the liver significantly influenced the intensity of the red colour only in the case of the 25% liver formulations. The colour parameter b* (yellow-blue) showed a decreasing trend on the surface of the products, more pronounced for the beef liver formulations. Nevertheless, statistically, only the type of liver introduced had a significant influence on this parameter ($p<0.0001$).

The colour per section of the four batches of sausages was significantly affected by both factors under consideration (type and percentage of liver). An increase in the colour parameters a* and b* was observed with the increase in the percentage of the liver, which may be attributed to the more intense colour of the liver due to a higher amount of pigments, such as myoglobin and hemoglobin. The brightness parameter L* per section exhibited a significant increase in value for the pork liver formulation, potentially due to the higher percentage of added fat in this particular sausage sample. The amount of fat in sausages significantly impacts the final colour of the product (Serdarogl M. & Ozsumer M. S., 2003; Estèvez M. *et al*, 2005). When comparing the results obtained in the present study to those described by Florowski T. *et al* (2021), we observed lower values for lightness, higher values for the a* parameter (green-red), and values that are approximately similar for the b* parameter (yellow-blue). Moreover, the values for lightness and yellowness differed from those documented by Estèvez M. *et al* (2005), who reported values of approximately 66 for lightness and 13 for yellowness.

Table 3

Effects of different liver type and various percentages of added liver on pH and colour (CIE L*, a*, and b* values) of sausages

Parameters / Samples		BL25	BL50	PL25	PL50	Significance of influence factors (p value)		
						F1	F2	F3
	pH	6.64±0.25[b]	6.89±0.07[c]	6.39±0.008[a]	6.38±0.04[a]	**<0,0001**	0.059	**0.041**
Surface colour	*L**	39.51±1.04[c]	33.99±1.31[b]	31.51±0.94[a]	30.99±0.51[a]	**<0,0001**	**<0,0001**	**<0,0001**
	*a**	10.33±0.22[a]	14.46±0.41[c]	13.05±0.49[b]	15.20±0.45[c]	**<0,0001**	**<0,0001**	**<0,0001**
	*b**	10.50±0.43[b]	9.63±0.56[b]	7.36±0.63[a]	7.34±0.47[a]	**<0,0001**	0.078	0.093
Section colour	*L**	51.22±1.78[c]	49.67±0.54[bc]	42.28±1.51[a]	47.54±0.42[b]	**<0,0001**	**0.004**	**<0,0001**
	*a**	10.80±1.03[a]	13.53±0.05[b]	13.30±0.47[b]	15.44±0.12[c]	**<0,0001**	**<0,0001**	0.271
	*b**	10.01±0.50[b]	11.71±0.03[c]	9.12±0.62[a]	10.13±0.03[b]	**<0,0001**	**<0,0001**	0.068

BL25 - sausages with 25% beef liver; BL50 - sausages with 50% beef liver, PL25 - sausages with 25% pork liver, PL50 - sausages with 50% pork liver, F1 - liver type; F2 - % of liver; F3 – liver type and % interaction;

The proximate compositions of the sausage formulations are presented in *Table 4.* It was observed that formulations containing 50% liver content, both from pork and beef batches, exhibited significantly higher moisture content and notably lower fat content. The elevated moisture content in these finished products can be attributed to the liver's higher water content in comparison to muscle tissue, as supported by previous findings (Biel W. & Kowalczyk A., 2019), which reported a moisture percentage of 70.00% in beef liver as opposed to 66.00% in *Musculus semitendinosus*.

Similarly, fat content displayed higher average values for sausages with 25% liver, a result of the elevated lipid content in the pork trimmings used in the formulation, along with the fat content naturally present in the liver (12.14%, Biel W. & Kowalczyk A., 2019), indicating an inverse relationship with moisture content.

Regarding the protein content of liver sausage formulations, it was observed that higher mean values were present in formulations with a greater amount of liver. However, statistically significant differences were only noted for beef liver formulations *(table 4).*

These variations arise from the distinct chemical compositions of the raw materials employed in the formulation. The liver exhibits a higher protein content in comparison to muscle tissue, with beef liver containing approximately 20.30% protein (Biel W. & Kowalczyk A., 2019), pork liver containing about 22.05% protein (Seong P. N. *et al*, 2014), and pork meat ranging from 18.13% to 19.19% protein (Zomeño C. *et al*, 2023).

The results obtained in this study are consistent with other research findings, albeit influenced by the specific composition of the raw materials and the processing methodology. Consequently, the protein content data obtained in our study surpass the 11.3% protein content reported by Yessimbekov Z. *et al* (2021) for liver patties, yet they are lower than the figures documented by Florowski T. *et al* (2021), who reported protein content of 24.0% in the control sample of liver sausage formulations that incorporated peanut paste.

Table 4

Proximate composition of liver sausages formulations

Samples	BL25	BL50	PL25	PL50	Significance of influence factors (p value)		
					F1	F2	F3
Moisture	60.90±0.22[a]	66.4±0.20[d]	62.34±0.33[b]	65.76±0.15[c]	<0,0001	<0,0001	<0,0001
Fats	20.32±0.25[d]	13.4±0.18[a]	18.48±0.45[c]	14.20±0.18[b]	0.001	<0,0001	<0,0001
Proteins	17.68±0.04[a]	19.34±0.13[b]	18.14±0.11[b]	19.18±0.08[b]	<0,0001	<0,0001	<0,0001
Collagen	15.82±0.08[a]	17.54±0.34[b]	16.3±0.12[b]	17.4±0.07[b]	<0,0001	<0,0001	<0,0001

Means with different superscripts within the same row are significantly different ($p < 0.05$). Data are means ± standard error.
BL25 - sausages with 25% beef liver; BL50 - sausages with 50% beef liver, PL25 - sausages with 25% pork liver, PL50 - sausages with 50% pork liver, F1 - liver type; F2 - % of liver; F3 – liver type and % interaction.

The sensory attributes, including appearance, colour, flavour, hardness, and overall acceptability, as perceived by the group of evaluators, are depicted in Figure 1 for sausages formulated with two different percentages of pork and beef liver. The values for appearance were higher for the beef liver formulations. Furthermore, the most noticeable differences in the perception of appearance were observed between formulations with different liver types, with formulations containing 25% liver being generally more favoured.

The evaluators' assessment of colour was strongly associated with brightness intensity, where samples formulated with beef liver exhibited the highest L* lightness values both on the surface and in cross-section, and were thus more highly appreciated. Sample PL25 received the lowest score in terms of colour, possibly due to the effect of lower lightness intensity, which was correlated with the heightened intensity of the red hue. This variance altered the evaluators' perception and made it distinct from the other samples.

In terms of flavour, the primary distinctions noted by the evaluators were between the two levels of liver content introduced, namely 25% and 50%. Consequently, the flavour of the samples with 25% liver was more positively assessed, receiving higher average scores.

Firmness, as defined, represents the force required to penetrate a product, serving as an indicator of the degree of hardness of its constituent parts and their level of cohesion. In the current study, the samples containing 25% liver (BL25 and PL25) were noted by the evaluators to exhibit greater firmness when compared to those formulated with 50% liver. This evaluation by the evaluators could be attributed to the fact that the liver, being an organ, lacks the elasticity provided by muscle fibres and is characterized by its smooth muscle texture. Moreover, firmness may be closely linked to the chemical composition, with higher firmness often associated with lower moisture content.

Lastly, the overall acceptance of the sensory quality of the four sausage samples was predominantly influenced by the perceived flavour and external appearance, with the highest rating being awarded to PL25.

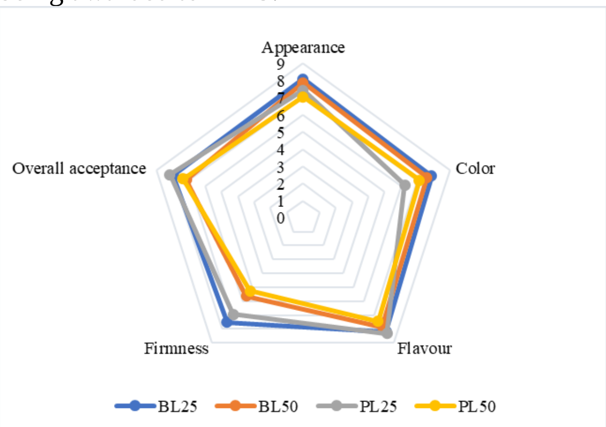

Figure 1 **Sensory traits of liver sausages; BL25 - 25% beef liver; BL50 - 50% beef liver, PL25 - 25% pork liver, PL50 - 50% pork liver**

CONCLUSIONS

The type and percentage of liver exert a notable influence on the colour of liver sausages. Specifically, increasing the liver percentage led to significant alterations in product colour. These alterations included a decrease in lightness (L*) for beef liver sausages and a noteworthy increase in the red hue (a*) for both beef and pork liver sausages. However, the impact of liver type was more pronounced in the case of the 25% liver formulations. The colouration per section of the sausages was also influenced by the type and liver percentage, resulting in significant increases in a* and b* as the liver percentage increased.

Based on the provided information, it was evident that the chemical composition of the produced sausage varieties exhibited significant variations in response to the percentage of liver incorporated into the recipe. Formulations containing 50% liver, both beef and pork, displayed higher moisture content and lower fat content when compared to formulations containing 25% liver. These distinctions can be attributed to the liver's elevated water content relative to muscle tissue and the fat content of the meat trimmings employed. Furthermore, protein content increased with a higher liver percentage, particularly in the case of beef liver formulations.

The sensory perception of the evaluators was influenced by the two factors, with the percentage of liver in the manufacturing technology most obviously influencing the perception and preference of the evaluators. The overall acceptability was higher for formulations with 25% liver.

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